The Link between Earthquakes and Nuclear Testing

Data suggests that many earthquakes occur as a result of nuclear testing, yet fewer 'killer quakes' have struck since testing began.

Is there a secret military agenda to control the number and strength of earthquakes?

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This paper is an attempt to understand distributions, patterns and directions of large earthquakes of Richter magnitude (M) greater than or equal to 6 (>=6) since 1900. Secondly, attempts will be made to relate such large earthquakes to the patterns of nuclear testing. Such testing is conducted by the United States (USA), the [former] Soviet Union (USSR), France, the United Kingdom (UK) and China. Emphasis was placed on earthquakes of M>=6 because these are the ones that cause considerable property damage and/or kill hundreds of people in short periods of time. Further, the data was more manageable when such magnitude earthquakes were considered. For example, there are between 5,000 to 7,000 earthquakes of M>=4.5 each year around the world, whereas in any given year since 1900, the highest number of earthquakes M>=6 was 214 (in 1957). As the magnitude threshold is lowered, many thousands more small events must be screened.

Earthquakes have always been part of the Earth's geologic history. On the other hand, nuclear testing only began in earnest in 1951. In 1963, such testing was moved underground. The greatest recorded earthquake death toll of 830,000 was in Shaanxi, China, in 1556. The worst in this century was on 28th July 1976 when the north-eastern Chinese city of Tangshan was levelled and about 800,000 people were killed. That quake measured M7.8. Coincidentally, five days before the quake (23rd July), the French detonated a nuclear bomb in the South Pacific Mururoa Atoll, and, one day before (27th July), the USA detonated a nuclear bomb of 20-150 kilotons (KT) at the Nevada test site.

The nuclear era began on 16th July 1945 when "Trinity" was dropped 100 feet from a tower near Alamogordo, New Mexico. The yield was 19 KT of TNT equivalent. Soon after this test, on 5th and 9th August, the 15-KT nuclear device, "Little Boy", was dropped on Hiroshima, and the 21-KT "Fat Man" was dropped on Nagasaki, ending World War II.

Since 1945, the major powers have exploded a total of over 1,800 nuclear bombs (through March 1989). An average of close to 50 underground nuclear tests have taken place each year since 1980. There is little doubt that planet Earth is under severe environmental stress. It is not getting any better.

Recently the prestigious environmental research group, the Worldwatch Institute, issued their latest *State of the World* report which shows that the world is being pushed to the brink. "We are losing at this point, clearly losing the battle to save the planet," said the report's chief author, Lester Brown. The impending result, he warned, "will shake the world to its foundation". Ozone depletion, toxic wastes, acid rain, water scarcity and pollution, forest destruction and topsoil loss are all part of this impending environmental disaster. Perhaps it is high time to consider underground nuclear testing as a part of this infamous list.

Patterns of Earthquakes, M>=6, 1900 to 1988

For means of comparing patterns and trends of M>=6 earthquakes with nuclear testing, 1950 will be used as the watershed year. There were no nuclear tests in that year, and only nine covering the years 1945 through 1949. The idea is to identify patterns in the first half of this century (1900 to 1949) and compare these to the second half of the century (1950 to 1988).

The most evident trend from Table 1 is the change in the comparative number of earthquakes of various magnitudes for the period before and after 1950. The first 50 years of this century recorded 3,419 such earthquakes of M>=6, an average of 68 per year. The last 39 years of this century recorded 4,963 earthquakes of M>=6, an average of 127 per year. In other words, the average per year for such earthquakes has about doubled in the second half of this century as compared to the first half of the century. Also, from 1900

through 1949, there were only eight years in which there were over 100 earthquakes of M>=6. This entire cluster of eight was found between 1931 and 1941. The highest number was 182 in 1934, and this compared to a low of 17 in 1904.

Starting in 1950, the trend was completely reversed. In this 39-year period from 1950 to 1988, the overwhelming majority of years had a total of over 100 earthquakes of M>=6. Again, this compares to only eight years for the first 50 years of this century. The highest number was 214 in 1957, while the lowest was 78 in 1962. It is interesting to note that the years 1959 and 1960 were relatively free of nuclear tests. Coincidentally, two years later, the number of earthquakes M>=6 dropped to only 78 in 1962 and 83 in 1963. These earthquake totals were the lowest for any given year covering the entire second half of this century.

When the M>=6 earthquakes are divided into groups, another trend becomes evident. From 1900 through 1949, there was a total of 101 earthquakes of M>=8, with a yearly maximum of 7 in 1906. Those 1906 earthquakes included the famous San Francisco earthquake of 18th/19th April, at M8.3, which killed over 400 people. But from 1950 through 1988, a total of only 30 earthquakes of M>=8 were recorded. The most in any given year since 1949 were four, back in 1950. This included the great Indian earthquake of 15th August, at M8.7, which killed over 1,500 people.

Thus, for the first half of this century, 101 earthquakes of M>=8 were recorded, as compared to only 30 of such earthquakes for the second half of the century. And for the last 10 years there have been only three earthquakes M>=8 recorded. The last was on 20th October 1986 when an M8.3 earthquake struck the Kermadec Islands of the South Pacific. This quake happened just four days after the USA exploded a 20-150-KT bomb in Nevada on 16th October.

It appears, therefore, that given such an increase in earthquakes of M>=6 since 1950, and a decrease in earthquakes of M>=8, the observed increase must have occurred in between the two magnitude ranges. In fact, the increase has mostly occurred in the M6.0 to 6.5 range, as seen in Table 1. The average number in this range per year has tripled since 1950, from 24 to 72, as compared to earthquakes between M6.5 to <7.0. The numbers for earthquakes M>=7 have dropped since 1950 relative to the first half of the century. There were 1,145 (an average of 22 per year) from 1900 to 1949, and only 699 (average of 17 per year) from 1950 to 1988.

Table 1: Earthquakes of Magnitude 6 or Greater

Magnitude	1900-1949	Average	1950-1988	Average
6.0 to <6.5	1164	24	2844	72
6.5 to <7.0	1110	22	1465	37
>7.0	1145	23	699	18
>8.0	101	2	30	<1

It should be noted that the ability to locate earthquakes in the world has increased dramatically since the turn of the century because of improved global communications and seismograph instrumentation. A dramatic increase in the number of recording stations has also occurred. For example, about 350 seismograph stations were operating in 1931, whereas today there are over 3,000 active stations around the world. It is generally conceded, however, that the largest earthquakes have been recorded relatively consistently since 1900, and these factors could have only a small effect on the number of events located per year for magnitudes above 6.0.

In conclusion, since 1950 the trend of the earthquakes M>=6 is as follows. There have been 1,500 more in the last half of this century compared to the first half, and the average per year has doubled. Further, the increase has been most dramatic in the M6.0 to 6.5 range, while a dramatic drop is seen in earthquakes of M>7.0. The question remains as to whether this trend will continue.

Patterns of Nuclear Testing, 1945 to 1989

The table below compiles the respective summary totals of nuclear explosions by country since 1945. The USA and USSR account for about 87% of the total.

Table 2: Total Nuclear Tests by Country, 1945 to 1988

Years	USA	USSR	Fra.	UK	Chin	India
1945 - 1962:	304	166	8	23	0	0
1963 - 1988:	629	451	165	18	32	1
Totals:	933	617	171	41	32	1

Grand Total: 1795

Nuclear testing began in earnest in 1951 when the USA exploded 16 bombs. They later tested 77 times in 1958, half in the Pacific and about half at the Nevada test site. In 1962, a record of 98 USA bomb tests occurred, including a 600-KT bomb from a Polaris A2 rocket in the Pacific.

The largest nuclear test explosion conducted by the USA was a 15-megaton (MT) bomb detonated at Bikini Atoll, Marshall Islands, on 28th February 1954. The largest nuclear test by any country is believed to have been a 58-MT bomb detonated by the USSR on 30th October 1961 above the high Arctic island of Novaya Zemlya. Since 9th November 1962, all USA nuclear tests have been conducted underground at the Nevada test site.

In 1962, a large number of nuclear tests were carried out (98 by the USA, 44 by the USSR) in anticipation of a halt to above-ground testing, which was a result of the Limited Test Ban Treaty signed in 1963. The French, however, continued to test above the water at Mururoa Atoll until 1975. And the Chinese did likewise, testing some 16 times above ground at the Lop Nor test site in Sinkiang Province until 1975. Tests are now limited to a maximum yield of 150 KT under terms of the Threshold Test Ban Treaty signed by President Richard M. Nixon and Soviet Premier Leonid Brezhnev in Moscow on 3rd July 1974. The ban did not take effect until 31st March 1976, and remains unratified by the US Senate. Testing was stopped completely in 1959 and 1960, and the USSR unilaterally stopped testing during a self-imposed moratorium for 19 months between July 1985 to February 1987. During that time, the USA conducted 26 nuclear tests. Since 1963, nuclear test sites by the five major powers have essentially been confined to the following locations:

Table 3:

Nation	Site Description	Latitude	Longitude
USA & UK:	Nevada Test Site (65 miles NW of Las Vegas)	37 N	116 W
France:	Mururoa, Fangataufa Atoll (720 miles SE of Tahiti, in Tuamotu archipelago)	22 S	139 W
China:	Lop Nor, Sinkiang Province	41 N	88 E
USSR:	1. Semipalatinsk, Kazakhistan	49 N	78 E
	2. Novaya Zemlya Island Arctic Ocean	73 N	55 E
	3. Ural Mountains, near Serov	60 N	56 E
	4. Siberia, north Lake Baykal	61 N	112 E

The French testing site is very close to the Tropic of Capricorn (23.5°S Lat.) and is the only nuclear test site south of the equator. The Soviet Arctic site, the Novaya Zemlya Islands, is the only nuclear test site north of the Arctic Circle (66.5°N Lat.) and is presently used only once or twice per year. However, from 1958 through 1963 it was the main Soviet nuclear test site. The site was last used on 4th December 1988 when the USSR exploded a nuclear bomb between 20-150 KT. Three days later, on 7th December, the Soviet Armenian earthquake struck, registering M6.9 and killing upwards of 60,000 people, injuring 13,000 and leaving half a million people homeless. Another of these dangerous coincidences.

The total nuclear tests by all countries since 1945 is 1,795. The average for the 43.5-year period is one test every eight to nine days. If the period 1963 through 1988

is taken, the major powers are averaging a nuclear test every 7.3 days. The yearly average in the 1960s was 56; in the 1970s it was 47 tests; and in the 1980s, 47 tests. But the period of July 1985 to February 1987 was the self-imposed test ban by the USSR, so the 1990s should show the yearly level rise to above 50 again as they try to make up for lost ground.

Perhaps the only hope on this nuclear testing path is the attempt to limit nuclear tests to 1 KT with a view to total elimination. The Soviets emphasised a goal of immediate cessation of all nuclear tests, while the Americans stressed the need to improve verification capabilities and the need to continue testing in the absence of significant reductions in offensive nuclear weapons.

In 1988, each side visited the other side's nuclear test site to monitor an underground nuclear explosion. The idea was to make sure that both sides can verify whether a test yields more or less than 150 KT. The Soviets prove accuracy by their preferred monitoring method, which counts seismic units such as those used in monitoring earthquakes. In the American method, an electrical cable must be placed within 10 to 15 metres of the blast.

Nuclear Testing and Earthquake Frequencies

The distribution of all earthquakes of M>=5.8 between 1900 through 1949 clearly reflects the boundaries of the 11 major tectonic plate zones. All such earthquakes were located in zones or blocks of 10 degrees of latitude and 10 degrees of longitude, to give frequency and per-cent distributions on a global scale. The highest per cent is the Southern Philippines block at 3.95%, having recorded 135 earthquakes of M>=5.8 during the period. Japan, in the Hokkaido area, is next at 3.07%, with 105 such earthquakes.

Table 4, below, identifies the major zones of high earthquake frequency, in some cases combining the values for adjacent blocks of latitude and longitude.

Table 4: Zones of High Earthquake Frequency (M>=5.8), 1900 to 1949 (1 block = 10° of Lat. x 10° of Long.)

Location	Number of Earthquakes	Combined no. of Blocks of Lat and Long	% of All Earthquakes
Indonesia, New Guinea:	424	7	12.39%
Vanuatu, Fiji, Tonga:	377	5	11.03%
Japanese Islands:	310	4	9.07%
Cent. Amer., S. Mexico:	205	4	5.99%
Chile, Peru, N. Argent.:	204	5	5.96%
Philippines:	187	2	5.47%
Taiwan:	74	1	2.16%
N. India, Pakistan:	69	1	2.02%
New Zealand:	43	3	1.25%
S. Greece, W. Turkey:	42	1	1.23%

This convention for aggregating and presenting the data in percentage values within blocks of latitude and longitude, is used throughout this paper.

These area blocks or zones of latitude and longitude received nearly 56% of all the Earth's quakes of M>=5.8 from 1900 to 1949, for a total of 1,935 earthquakes. By comparison, all other blocks of latitude and longitude each receive less than 1% of all earthquakes. This established pattern of earthquakes of M>=5.8, with highlighted zones of high frequency occurrence on a global scale between 1900 and 1949, will act as a control against which we can compare the patterns of earthquakes that follow nuclear testing. All such earthquakes were recorded either on the day of the test or within the four days afterward, for a five-day period.

Atmospheric (Above-Ground) Nuclear Testing

The first area to consider is the Pacific Ocean. The US tests here totalled 106 and were conducted from 1946 through 1962. The principal sites are listed below:

Table 5:

Location	Number of Tests	Lat	Long
Eniwetak	43	11 N	162 E
Christmas Island	24	2 N	169 W
Bikini	23	11 N	165 E
Johnson Island	12	17 N	169 W
Pacific sites	4		

When we review the earthquake data, the following areas emerge as receiving more than their share of the M>=5.8 earthquakes. Hardest hit following USA Pacific tests, relative to the pattern prior to 1950, were the blocks of latitude and longitude encompassing Sakhalin Island, the Aleutian Islands, Peru, Bolivia, Central America, Western Samoa, Vanuatu, Baja, California, Hawaii and Japan.

French testing in the South Pacific covered years 1966 through 1974 when they conducted 44 atmospheric tests, 39 over Mururoa Atoll and five over Fagataufa Atoll. The earthquake pattern after the French South Pacific testing is somewhat different, and the zones of high frequency earthquakes following these French tests were Western Samoa, Fiji, the Solomon Islands, the Alaska Panhandle, and the area between the Kamchatka Peninsula and Aleutian Islands. Interestingly, these regions of high earthquake activity following Pacific nuclear testing are all confined to the Pacific Ring of Fire, a zone of earthquakes and volcanoes that circles the entire Pacific Ocean. These data are summarised in Table 6.

British tests in the Pacific Ocean covered the period 1957 to 1958 and involved only

Table 6: Percentage of All Earthquakes (M>=5.8) after US and French Above-Ground Nuclear Tests, Pacific Ocean, 1946 to 1975 (five-day period)

Location	Pre-Test Period Percent 1900-1949	After USA Tests Percent 1946-1963	After French Tests Percent 1966-1975
W. Samoa:	2.78	4.91	12.50
Fiji:	2.31	2.45	4.17
Kermadec Is.:	0.50	1.84	0
Vanu-Coral Sea:	3.36	6.75	4.17
Solomon Is.:	2.98	1.84	16.67
Hawaii:	0.06	1.23	0
	0.09	1.84	0
N. Peru:	1.02	0.61	4.17
Lima, Peru:	1.26	3.07	0
Bolivia:	0.79	3.07	0
C. Rica, Panama:	1.05	4.91	0
South Mexico:	2.22	4.29	0
Baja, CA:	0.35	2.45	0
Alaska Pannan.:	0.50	0	8.33
W. Alaska:	0.41	1.23	4.17
Aleutian Is.:	0.88	7.36	0
	0.97	3.07	4.17
	0.88	2.45	4.17
	0.76	0.61	4.17
Sakhalin:	0.97	7.98	0
Hokkaido:	3.07	1.84	4.17
Tokyo:	2.46	3.68	0
S.Japan, Bonin:	0.53	2.45	0
Burma:	0.94	0	4.17
Tehran:	0.47	0	4.17

nine tests at Christmas Island (1.7°N Lat, 157°W Long). Twelve British tests were conducted in Australia from 1952 to 1957. Since 1962, all British tests have been underground at the USA Nevada test site. Only the Christmas Island tests were examined here, but, once again, familiar terms emerge. See Table 7.

Table 7: Percentage of All Earthquakes (M>=5.8) after British Above-Ground Nuclear Tests, Pacific Ocean, 1952 to 1957 (five-day period)

Location	1900-1949	After British Tests
Central America & S. Mexico:	4.64	20.00
Kermadec Is./Samoa:	7.13	15.00
Solomon Is./Vanuatu:	6.34	10.00

From 1951 until 1963, the USA tested 100 times above ground at the Nevada test site. When these test dates are matched with earthquakes of M>=5.8 within a five-day period, the following areas show a higher-than-normal share of such earthquakes compared to the 1900-1950 period:

Table 8. Percentage of All Earthquakes (M>=5.8) after USA Above-Ground Nuclear Tests in Nevada, 1951 to 1963 (five-day period)

Location	1900-1949	After USA Tests
Kermadec/W. Samoa & Vanuatu:	11.61	16.05
Kamchatka/Aleutian Is.:	4.46	10.82
Taiwan:	2.16	5.60
Solomon Is.:	2.98	5.22

The Soviet above-ground testing involved 166 tests from 1949 to 1962. About 70% of the known Soviet tests have occurred at their two main sites near Semipalatinsk in eastern Kazakhstan (50%), and on the island of Novaya

Zemlya, north of the Arctic Circle (20%). The above-ground testing was very active at Novaya Zemlya in the years 1958 to 1962. When the 79 tests at that site are matched to the M>=5.8 earthquakes over the five-day period for those years, the following areas emerge as high-risk zones:

Table 9: Percentage of All Earthquakes (M>=5.8) after USSR Above-Ground Nuclear Tests in Novaya Zemlya, 1958 to 1963 (five-day period)

Location	1900-1949	After USSR Tests
Costa Rica/Panama:	1.05	8.82
Mindanao, Philippines:	3.95	6.86
Vanuatu:	3.36	5.86
Kermadec Is.;	2.81	6.86
Kamchatka:	0.97	5.88
Java/Java Trench:	0.94	8.82
S. Aleutian Is.:	1.85	10.76

These seven areas were struck 55% of the time during a five-day period following an above-ground test at Novaya Zemlya, for the period 1958 through 1962.

The [former] USSR's main testing site today is Semipalatinsk. But from 1945 through 1962, only a total of 53 above-ground tests were recorded. This number also included tests conducted at their other mainland sites in Siberia and the Ural Mountains. Two regions are most noticeably tied to this particular Soviet nuclear test site: Taiwan at 9.48%, and the South Aleutian Islands at 23.28%. These two locations respectively received only 2.16% and 0.88% of all M>=5.8 earthquakes during the pre-testing period of 1900 to 1949. Two other high-percent zones are the southern Mexico-Central America coastal region at 8.62%, and the western Samoa-Tonga region at 9.48%.

Another very interesting observation is that these mainland Soviet tests appeared to have little significant effect upon earthquake patterns in the Indonesia-Solomon Islands region, a zone that appears tied to other above-ground nuclear test sites.

Underground Nuclear Testing

Underground or below-ground nuclear testing for the USA and USSR started in 1963. Through to 1988 the USA tested underground 629 times, almost exclusively at the Nevada test site. The Soviets tested underground 451 times, mainly at the Semipalatinsk location, but with 35 underground tests at Novaya Zemlya.

Table 10. Percentage of All Earthquakes (M>=5.8) after USA Below-Ground Nuclear Tests in Nevada, 1963 to 1988 (five-day period)

Location	1900-1949	After USA Tests
Vanuatu:	3.36	6.81
Solomon Islands:	2.98	4.89
Nevada:	0.61	4.38
Aleutian Is. Block:	3.31	12.57
Santiago, Chile:	0.76	2.79

Observations from Table 10 show that around 30% of the time, during a given five-day period following an underground nuclear test in Nevada, an M>=5.8 earthquake has hit the Vanuatu Islands, Solomon Islands, Nevada itself, parts of the Aleutians, or Santiago, Chile.

The 35 tests at Novaya Zemlya, 1963 through 1988, tie to familiar areas again, as given in Table 11 below:

Table 11: Percentage of All Earthquakes (M>=5.8) after USSR Below-Ground Nuclear Tests in Novaya Zemlya, 1963 to 1988 (five-day period)

Location	1900-1949	After USSR Tests
S. Aleutians:	0.76	9.09
Mindanao:	3.95	9.09
Vanuatu:	3.36	6.06
Hokkaido:	3.07	6.06
Novaya Zemlya:	0	18.18
W. Samoa/Kermadec Is.:	5.59	15.15

The major [ex-]USSR nuclear test site in Semipalatinsk and associated mainland sites have received over 400 underground nuclear tests since 1963. Interesting patterns of earthquakes again follow nuclear tests at these sites. The South Pacific zone once again shows a relationship, but so too does the Nevada region, which previously only appeared with a high percentage following American nuclear tests in Nevada itself. The Aleutian Islands usually show an increase in earthquake frequency following nuclear tests, but this is not the case following a USSR underground test at Semipalatinsk, a marked contrast with the Novaya Zemlya test site. Further, the Semipalatinsk region itself received 3.15% of all M>=5.8 earthquakes following nuclear tests at that site, as compared to a low 0.23% prior to 1950. See Table 12.

Table 12: Percentage of All Earthquakes (M>=5.8) after USSR Below-Ground Nuclear Tests in Semipalatinsk and Other USSR Mainland Sites, 1963 to 1988 (five-day period)

Location	1900-1949	After USSR Tests
Solomon Is.:	2.98	8.92
Vanuatu:	3.36	6.49
Fiji, New Caledonia, Kermadec,W.Samoa block:	8.33	14.86
Honshu-Kyusnu:	2.19	2.43
Nevada:	0.61	1.62
Aleutians:	2.55	3.24
Semipalatinsk:	0.23	3.51

The French conducted 1,112 underground nuclear tests at Mururoa Atoll in the South Pacific from 1975 through 1988. As pointed out by a recent National Resources Defence Council paper, the French have accounted for some 20% of all nuclear tests within the 10 years to 1988. Serious fractures of the coral atoll and constant nuclear contamination of the site and surrounding waters has occurred. Some observers feel that the French will have to move these tests to the nearby Fagataufa Islands. When the earthquakes of M>=5.8 are mapped within five days following all French underground testing, many Pacific regions again emerged as most affected and noticeable. See Table 13.

Interestingly, the French nuclear test site itself at Mururoa Atoll (22°S Lat., 139°W Long.) has a low 1.55% earthquakes observed in the five-day period following an underground test. This is quite different when compared to earthquake frequencies following underground tests at the three other test sites in Nevada (4.36%), Semipalatinsk (3.51%), and Novaya Zemlya (18.18%). This might be attributed to the fact that energy released from an underground nuclear test dissipates differently from a test site surrounded by an ocean.

Table 13: Percentage of All Earthquakes (M>=5.8) after French Below-Ground Nuclear Tests at Mururoa Atoll, South Pacific, 1975 to 1988 (five-day period)

Location	1900-1949	After French Tests
W. Samoa, Kermadec Is.:	5.79	12.41
New Britain, Solomon Is.:	2.98	10.08
S. Aleutian zone:	2.61	7.76
Vanuatu:	3.36	9.30
Hokkaido:	3.07	5.43
Taiwan:	2.16	3.10
Mexico City, El Salvador:	2.22	3.10
Columbia:	0.85	2.33

Atmospheric and Underground Nuclear Tests Combined

When all the above-ground (atmospheric) nuclear explosions are considered, certain areas of the world reveal high frequency patterns of the M>=5.8 earthquakes following such tests. These areas, listed in Table 14, account for about 50% of all the M>=5.8 earthquakes that followed an above-ground nuclear explosion within the five-day period.

Table 14: Percentage of All Earthquakes (M>=5.8) after All Atmospheric Above-Ground Nuclear Tests Worldwide, 1950 to 1974 (five-day period)

Location	1900-1949	After Nuclear Tests
Kamchatka, Aleutians:	0.88	2.06
	0.97	2.06
	0.76	1.65
	0.88	7.27
	0.97	4.66
Vanuatu:	3.36	6.86
Solomon Is.:	2.98	4.39
Panama, Costa Rica:	1.05	4.12
S. Mexico, El Salvador:	2.22	3.57
Kermadec Is.:	0.50	3.43
	0.03	1.23
Taiwan:	2.16	3.29
S. Greece, Turkey:	1.23	2.06

The earthquake patterns following all underground nuclear tests are similar to those for the above-ground testing, and, when grouped together, account for about 50% of all the M>=5.8 earthquakes that follow an underground nuclear explosion.

It is interesting to note that the Nevada area has a 2.65% chance of having such an earthquake. This compares to 0.61% for the pre-nuclear 1900 to 1949 period, and is slightly more than Taiwan's 2.47%. See Table 15 below.

Table 15: Percentage of All Earthquakes (M>=5.8) after All Underground Nuclear Tests Worldwide, 1963 to 1988 (five-day period)

Location	1900-1949	After Nuclear Tests
Kamchatka, Aleutians:	0.89	1.06
	0.97	0.97
	0.76	3.35
	0.88	2.12
	0.97	1.85
	0.70	1.76
Vanuatu:	3.36	6.70
Solomon Is.:	2.98	6.70
Fiji, Tonga, Kermadec Is.:	2.05	1.59
	2.78	3.88
	2.31	3.88
	0.50	1.68
Hokkaido:	3.07	3.26
Papua, New Guinea:	2.22	3.09
Nevada:	0.61	2.65
Taiwan:	2.16	2.47

The continuation of underground nuclear bomb testing, mainly by the USA, [ex-] USSR and France, should alert certain areas of the world to note when and where the tests occur. Table 16 summarises the patterns of earthquakes of M>=5.8 within a five-day period following nuclear tests at various test sites.

Table 16: Percentage of All Earthquakes (M>=5.8) after Nuclear Tests at Various Test Sites (five-day period)

Area Affected	After USA /Nevada test	After USSR Semipala. test	After USSR Zemlya test	After French Mururoa test
Aleutian Is.:	12.57	3.24	9.09	7.76
Samoa, Kermadec:	—	14.86	15.15	12.41
Vanuatu:	6.81	6.49	6.06	9.30
Solomons, N. Brit.:	4.89	8.92	—	10.08
Mindanao, Philip:	2.09	—	9.09	—
Taiwan:	2.09	—	—	3.10
Papua, New Guin:	2.79	—	—	—
Hokkaido:	3.66	—	6.06	5.43
Honshu-Kyushu:	—	2.43	—	—
Novaya Zemlya:	—	—	18.18	—
Semipalatinsk:	—	3.51	—	—
Nevada:	4.36	1.62	—	—
Mexico, El Salv:	—	—	—	3.10
Santiago, Chile:	2.79	—	—	—
Totals:	42.05%	41.07%	63.63%	51.18%

Two areas show a significant tie to nuclear testing, regardless of who tests—notably, the Aleutian Islands chain and the South Pacific area inclusive of Vanuatu, the Solomon Islands, Western Samoa and the Kermadec Islands. Further, the Japanese islands of Hokkaido, Honshu and Kyushu should note who tests and when. The island of Mindanao should take some precautions when the [ex-]USSR test at Novaya Zemlya. For Nevada, it is necessary not only for them to monitor American tests, but also Soviet Semipalatinsk tests including the Urals and Siberia sites. The two most vulnerable areas in the South Pacific, the Solomon Islands and Vanuatu, should monitor tests weekly. Each of these areas has up to a 10% chance per week of having an M>=5.8 earthquake because of nuclear tests in the 1980s being conducted on an average of one per week.

The "Killer Earthquake" and Nuclear Tests

Of all the earthquakes that do occur, the most frightening of them is the one identified as the "killer quake". It can be defined as an earthquake which kills at least 1,000 people. It is especially interesting to note a dangerous coincidence when all the killer earthquakes since 1951 are simply listed and matched to the dates of nuclear tests. Table 17 (see page 16), displays the 'match' between nuclear explosions and killer earthquakes.

Each of the 32 killer earthquakes which struck between 1951 and 1988 caused at least 1,000 deaths, with the worst being 800,000 killed in the 1976 M8.2 China earthquake. This China earthquake was the worst for deaths recorded in this century, and, coincidentally, the US tested a nuclear bomb one day before the earthquake hit. Over the 37 years of nuclear testing, 20 of the 32 killer earthquakes, or 62.5%, occurred on the same day or within four days of a nuclear test. The total death toll for these 20 killer earthquakes is over one million people. Table 18 shows the breakdown of these 20 killer earthquakes.

Table 18: Twenty "Killer Earthquakes" Matched with Nuclear Tests, 1951 to 1988

Number of Quakes	Days after Nuclear Test
12	Same day, or 1 day later
3	2 days later
2	3 days later
3	4 days later

(When two or more nuclear tests occur prior to a killer quake, only the test closest to the quake date is counted.)

Is this pure coincidence?

Conclusions

Some people would question the idea of directly linking nuclear testing with the pattern of large, powerful earthquakes which follow within days of a test. Given the large number of such earthquakes per year, and the high number of nuclear tests per year, there might be a chance match between any given test and the occurrence of a large earthquake.

In the 1980s, there were an average of 47 tests and 120 earthquakes of M>=6 per year. While a chance correlation might appear to be at work, the geographical patterns in the data, with a clustering of earthquakes in specific regions matched to specific test dates and sites, do not support the easy and comforting explanation of "pure coincidence". The phenomenon clearly requires further study.

The primary purpose here was to identify frequency patterns of earthquakes following a given nuclear test. Obviously, more study and research of the question of a link between nuclear bomb tests and earthquakes is needed. This effort is simply a beginning. ∞

Selected References on the Environmental Effects of Nuclear Explosions:

- Babst, D. V. and A. Dely, "Nuclear Testing and Volcanic Activity", *Journal of Peace Research*, Brandon, Manitoba, Canada, June 1987, pp. 63-69.
- Bolt, B. A., Nuclear Explosions and Earthquakes: *The Parted Veil*, W. H. Freeman, San Francisco, CA, USA, 1976.
- Dahlman, O., et al., "Ground Motion and Atmospheric Pressure Waves from Nuclear Explosions in the Polynesian Test Area Recorded in Sweden, 1970", FOA 4 Report, C4461 26, 1971.
- Danielson, B. and M. Danielson, *Poisoned Reign*, Penguin Books, New York, NY, USA, 1986.
- Davidson, C. I., et al., "Radioactive Cesium from the Chernobyl Accident in the Greenland Ice Sheet", *Science* 237:633-634, 7 August 1987.
- Fieldhouse, R. W., et al., "Nuclear Explosions", *World Armaments and Disarmament*, SIPRI Yearbook, Oxford Uni. Press, NY, 1987, pp. 45-52.
- Fuller, J. G., *The Day We Bombed Utah*, New American Library, New York, USA, 1984.
- Goldblat, J. and D. Cox, "The Debate About Nuclear Weapon Tests", Occasional Paper No. 5, Canadian Institute for International Peace and Security, Ottawa, Canada, 1988.
- Harris, D. L., "Effects of Atomic Explosions on the Frequency of Tornadoes in the US", *Monthly Weather Review*, December 1954, pp. 360-369.
- Kato, Y., "Recent Abnormal Phenomena on Earth and Atomic Power Tests", *Pulse of the Planet*, 1(1):5-9, Spring 1989.
- "Lightning Increase After Chernobyl", *Science News* 312:238, 10 October 1987.
- Lall, R. G. and P. D. Brandes, *Banning Nuclear Tests*, Council on Economic Priorities, NY, 1987.
- Malcolmson, R. W., *Nuclear Fallacies: How We Have Been Misguided Since Hiroshima*, McGill-Queen's University Press, Kingston, Ontario, 1985.
- Matsushita, S., et al., "On the Geomagnetic Effect of the Starfish High Altitude Nuclear Explosion", *J. Geophysical Res.* 69:917-945, 1964.
- McEwan, A. C., "Environmental Effects of Underground Nuclear Explosions", *World Armaments and Disarmaments*, SIPRI Yearbook 1988, Oxford University Press, NY, 1988, pp.75-91.
- O'Keefe, B. J., *Nuclear Hostages*, Houghton Mifflin, Boston, Mass., USA, 1983.
- Reich, W., *The Oranur Experiment, First Report (1947-1951)*, Wilhelm Reich Foundation, Maine, USA, 1951 (partly reprinted in W. Reich, *Selected Writings*, Farrar, Straus & Giroux, 1960).
- Smith, R. J., "Scientists Implicated in Atom Test Deception", *Science* 218:545-547, 5 November 1982; "Atom Tests Leave Infamous Legacy", *Science* 218:266-269, 15 October 1982.
- Titus, A. C., *Bombs in the Backyard*, University of Nevada Press, Las Vegas, NV, USA, 1986.
- Trombley, A., "An Interview...", *Wildfire*, January 1988, pp. 17-33.

Editor's Postscript:

A couple of questions can be asked from a study of the data supplied in Gary Whiteford's article:

(1) Do the superpowers now have the capability of conducting a form of 'earthquake warfare' as a result of their nuclear bomb tests?

(2) Conversely, are the superpowers using nuclear bomb tests to prevent 'super earthquakes' of magnitude 8.0 or greater on the Richter scale? While it is true that the average number of medium-sized earthquakes (size 6.0 to 6.5 on the Richter scale) has tripled since nuclear testing began, the number of 'super quakes' has fallen.

Just before we go to print with this issue, France has detonated the first in its latest series of underground nuclear tests at Mururoa Atoll, on 6 September. So far, since then, four earthquakes of magnitude 5.5 or greater have struck, as follows:

• 8 September, Southern East Pacific Rise: Lat. 56.2°S, Long. 122.0°W, magnitude 5.7 at 00 27 49.2 hours UTC.

• 8 September, Southern East Pacific Rise: Lat. 56.1°S, Long. 122.0°W, magnitude 6.3 at 01 15 29.3 hours UTC (not considered an aftershock, as far as we can tell from the data).

• 8 September, off the coast of Chiapas, Mexico: Lat. 14.9°N, Long. 94.2°W, magnitude 5.5 at 17 25 49.1 hours UTC.

• 9 September, Northern Chile: Lat. 20.2°S, Long. 69.3°W, magnitude 5.6 at 20 58 40.2 hours UTC.

Although this article has dealt with the relationship between earthquakes and nuclear bomb tests, several more alarming effects are linked to nuclear tests:

• In 1974, a scientist at the National Center of Atmospheric Research, Dr Matsushita, discovered that both the magnetic field of the Earth and the ionosphere were disturbed for 10 days to two weeks after an underground nuclear test. In 1977 he was forbidden by the US Government from taking measurements for two weeks after a test. His work was classified shortly thereafter.

• According to data from Tokyo University Aerospace Institute's satellite, *Taiyo*, nuclear testing has caused the temperature of the Earth's exosphere (outermost portion of the atmosphere, approx. 300 to 600 miles above the Earth) to rise abnormally by from 100° to 150°C.

• The satellite also showed that nuclear testing is the cause of abnormal polar motion of the Earth. The normal polar movement, which makes a revolution every 430 days, is called the "Chandler Cycle". In other words, the position of the pole shifts radically at the time of nuclear explosions.

(Sources: Wildfire Magazine, vol. 3, no. 3, Winter 1988, vol.4, no. 4, Spring 1989; Pulse of the Planet, Spring 1989)

Table 17: Killer Earthquakes, 1951 to 1988, Matched with Nuclear Tests (five-day period)

# Tests Per Year	Nuclear Test Date	Earthquake Date	Location	Magnitude	Deaths	Test/Quake Match?
17	1953: Mar. 17	Mar. 18	NW Anatolia	7.2	1,200	yes
33	1956: Jun. 6-16 (5 separate tests)	Jun. 10-17	Kabul, Afghanistan	7.7	2,000	yes
54	1957: —	Jul. 2	Iran	7.4	2,500	no
	1957: Dec. 9	Dec. 13	Iran	7.2	2,000	yes
3	1960: —	Feb. 29	Agadir, Morocco	5.8	12,000	no
	1960: —	May 22	Arauco, Chile	>8.3	5,000	no
145	1962: Sep. 1	Sep. 1	Buyin-Zara, Iran	7.1	13,000	yes
47	1963: —	Jul. 26	Skopje, Yugoslavia	6.0	1,100	no
67	1966: Aug. 19	Aug. 19	Varto, Turkey	6.9	2,600	yes
64	1968: Aug. 27, 29	Aug. 31	Dasht-e-Bayaz, Iran	7.4	12,000	yes
61	1970: Mar. 26, 27	Mar. 28	Gediz, Turkey	7.4	1,100	yes
	1970: May 28, 30	May 31	Chimbote, Peru	7.7	68,000	yes
46	1972: Apr. 11??	Apr. 10	Iran	6.9	5,100	??
	1972: Dec. 21	Dec. 23	Managua, Nicaragua	6.2	5,000	yes
46	1974: Dec. 27	Dec. 28	Pattan, Pakistan	6.3	5,200	yes
38	1975: Sep. 6	Sep. 6	Lice, Turkey	6.8	2,300	yes
45	1976: Feb. 4 (2)	Feb. 4	Guatemala City	7.5	23,000	yes
	1976: —	May 6	Italy	6.5	1,000	no
	1976: July 27	Jul. 28	Tangshan, China	8.2	800,000	yes
	1976: —	Aug. 17	Mindanao, Philippines	7.8	5,000	no
	1976: Nov. 23 (2)	Nov. 24	Eastern Turkey	7.9	5,000	yes
46	1977: —	Mar. 4	Bucharest, Romania	7.5	1,600	no
59	1978: Sep. 13, 15	Sep. 16	Tabas, Iran	7.7	25,000	yes
55	1979: —	Dec. 12	Colombia-Ecuador	7.9	800	no
55	1980: Oct 8	Oct. 10	Al Asnam, Algeria	7.3	4,500	yes
	1980: —	Nov. 23	Naples, Italy	7.2	4,800	no
57	1982: Dec. 10	Dec. 13	Dhamar, N. Yemen	6.0	2,800	yes
57	1983: Oct. 26	Oct. 30	Posinier, Turkey	7.1	1,300	yes
35	1985: —	Sep. 19	Mexico City	7.9	10,000	no
24	1986: —	Oct. 10	El Salvador	5.4	1,000	no
40	1988: Nov. 5	Nov. 6	Burma, China	7.3	1,000	yes
	1988: Dec. 4	Dec. 7	Armenia, USSR	6.8	60,000	yes